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BACKGROUND OF THE INVENTION

The present invention relates to a method for treating a load of ligneous material made up of stacked elements, particularly a load of wood, by high-temperature heat treatment. More particularly, the present invention relates to a method for thermally treating wood so that the treated wood at least retains, and potentially improves all of its characteristics, such as the mechanical, acoustic and insulating properties of the wood, together with the dimensional stability of the wood in the presence of moisture.

Such heat treatment allows the media that generate microorganisms and mold to be eliminated. Such heat treatment also allows chemical linking between the macromolecular chains of the constituents of the wood in a controlled atmosphere and at a minimum temperature of 230 degrees Celsius. The main qualities acquired during such high-temperature heat treatment are dimensional stability and markedly improved resistance to the kinds of attack that lead to ageing and rotting.

Co-owned French Patent Application No. 2 790 698 discloses a device for the high-temperature heat treatment of ligneous material. The disclosed device provides an enclosed treatment space for processing a load of ligneous material that is to be treated. The load of ligneous material develops, within the enclosed space, a first volume known as a "raised-pressure

chamber" which is situated upstream of the load to be treated, and a second volume known as a "recovery chamber" which is situated downstream of the load. Means are provided for heating a heat-transfer fluid circulating in the enclosed space, for continuously circulating the heat-transfer fluid, for monitoring the temperature and moisture content of the enclosed space, and for regulating the temperature and humidity of the enclosed space. Seals are provided for sealing the top and bottom of the load of material contained within the treatment space.

The disclosed device operates by continuously circulating a gaseous heat-transfer fluid which is formed of air, with its oxygen removed, and which is mixed with combustion gases to provide a neutral atmosphere. The heat-transfer gas is heated in successive steps, up to a minimum temperature of 230 degrees Celsius, which steps are defined on the basis of parameters associated with the ligneous material that is to be treated. The heat-transfer gas circulates continuously throughout the treatment cycle, from the point where the heat-transfer gas is heated, for example, by a burner, toward the load of ligneous material to be treated. The heat-transfer gas circulates at a flow rate and speed which are in equilibrium at every point along the developed circuit, uniformly supplying the heat-transfer gas with the heat energy needed for the heat treatment.

The disclosed treatment cycle requires several passes of the heat-transfer gas through the load. When the cycle is

completed, a drop in temperature takes place, in successive steps, by spraying high-pressure cold water in the heat-transfer gas circuit in the raised-pressure chamber. The pressure within the enclosed space is maintained, in the treatment zone, by a neutral gas which compensates for the reduction in volume of the heat-transfer gas during this cooling phase.

Although heat-treatment devices of this type are known, such devices continue to undergo development for purposes of allowing a higher level of safety and a higher level of quality and uniformity of the heat treatment across the various wood loads to be treated. It is, therefore, the object of the present invention to provide an improved method for the high-temperature heat treatment of a load of ligneous material made up of stacked elements, particularly a load of wood, which makes it possible to account for the behavior of the treated products in terms of their thermal conductivity and their resistance to the release of liquid or degradable substances under the effect of high temperature.

SUMMARY OF THE INVENTION

To this end, and in accordance with the present invention, a method is provided for treating a load of ligneous material made up of stacked elements, particularly a load of wood, by high-temperature heat treatment in an enclosed treatment space which includes various components for processing the load of

ligneous material to be treated.

The load of ligneous material defines, within the enclosed space, a first volume known as a "raised-pressure chamber" which is situated upstream of the load to be treated, and a second volume known as a "recovery chamber" which is situated downstream of the load. A heater is provided for heating a heat-transfer fluid circulating in the enclosed space. The heat-transfer fluid is continuously circulated, and the temperature and moisture content of the enclosed space is monitored, for regulation of the temperature and humidity of the enclosed treatment space. Seals are provided for sealing the top and bottom of the load of material.

In accordance with the present invention, the atmosphere in each of the chambers is continuously monitored using sensors for measuring the temperature and moisture content of the enclosed space. Data received from the sensors is then compared, for simultaneously and uniformly adjusting the heating and, if appropriate, the cooling of the heat-transfer fluid, to perform a heat-treatment cycle. The rise in temperature of the heat-treatment cycle is either linear, or proceeds in steps, with such temperature step levels and their duration being preestablished. The rise in temperature is then governed, as a function of the behavior of the load of ligneous material, in terms of its thermal conductivity and as a function of equilibrium between the flow rate and the speed of the heat-transfer fluid between the two chambers.

Each of the temperature levels in the treatment cycle is advantageously reached when there is equilibrium between the temperature in the raised-pressure chamber and the temperature in the recovery chamber. Such equilibrium is determined using the following formulae:

$T1 = T2 - \Delta°C$, when the temperature in the treatment cycle is rising, and

$T2 = T1 + \Delta'°C$, when the temperature in the treatment cycle is falling,

where Δ and Δ' are temperature constants ranging between 5 and 25 degrees Celsius. In a preferred embodiment, the constants Δ and Δ' are respectively equal to 5 degrees Celsius and 20 degrees Celsius.

Further in accordance with the present invention, progression to a level at least equal to 100 degrees Celsius is permitted only if the volume of the enclosed space contains an oxygen content below 3%. Advantageously, if an incident is detected which involves heating of the enclosed space above a mean temperature in excess of 120 degrees Celsius, the temperature is regulated until a mean temperature of below 100 degrees Celsius is detected in the chambers before any resumption of the treatment cycle is permitted.

In another advantageous arrangement, electronic controls are provided for controlling the foregoing operations. The electronic controls are connected to computerized equipment that allows the data from the sensors arranged in the enclosed

space to be printed out during a treatment cycle, together with temperature curves, in real time.

In another advantageous arrangement, the speed at which the heat-transfer fluid circulates is kept constant in the enclosed treatment space by monitoring the speed of circulation and by adjusting the flow rate of the heat-transfer fluid.

Further description of an exemplary embodiment of the present invention is provided hereafter, with reference to the following drawing.

BRIEF DESCRIPTION OF THE DRAWING

The single attached figure illustrates a vertical section of a device for the high-temperature heat treatment of a ligneous material.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

The single figure shows an enclosed space 1 in the form of an oven which is generally comprised of four vertical walls 2 and a roof 3. At least one of the vertical walls 2 of the enclosed space 1 is provided with a door 4 so that a ligneous material 5 to be treated can be loaded into the oven.

The illustrated load of ligneous material 5 is made up of wooden planks 6 stacked on top of one another to form a more or less parallelepipedal structure when placed inside the

enclosed treatment space 1. The planks 6 are advantageously placed so that their length is in the longitudinal direction of the enclosed space 1, and so that they are separated from one another by spacers 7 placed in a transverse direction. The thickness of the spacers 7 is defined according to the thickness of the wood that is to be treated, the dimensions of the load 5 and the physical parameters relating to circulation of a fluid in the enclosed space 1 and through the load 5.

The load 5 of ligneous material to be treated defines, within the enclosed space 1, a first volume 8 situated upstream of the load 5, which will hereafter be referred to as a "raised-pressure chamber", and a second volume 9 situated downstream of the load 5, which will hereafter be referred to as a "recovery chamber".

The enclosed space 1 is provided with various components which are known from French Patent Application No. 2 790 698, which is incorporated by reference as if fully set forth herein. A heater 10 is provided for heating a heat-transfer fluid, which can be a gas, such as air, and which is to circulate in the enclosed space 1. A blower 11 is provided for continuously circulating the heat-transfer fluid through the enclosed space 1. Sensors 14, 15 are provided for respectively monitoring the temperature and the moisture content of the enclosed space 1. A regulator 12 is provided for regulating the temperature and the humidity of the enclosed space 1. Seals 16, 17 are provided for respectively sealing the

top and the bottom of the load of material 5, to prevent the heat-transfer fluid from following the path of least resistance through the load. Programmable electronic controls (not shown) are provided for controlling temperature variation step levels and moisture content in the enclosed treatment space 1.

As an illustration, the heater 10 for heating the heat-transfer fluid is comprised of at least one gas burner arranged in the upper part of the enclosed space 1, in a chamber 13 which will hereafter be referred to as a "heating chamber". The blower 11 is comprised of at least one fan for drawing the heat-transfer fluid from the recovery chamber 9 and for discharging the heat-transfer fluid into the heating chamber 13. The regulator 12 is comprised of a horizontally disposed, high-pressure water spray boom 12 situated in the raised-pressure chamber 8. The spray boom 12 is provided with a plurality of nozzles for spraying a high flow rate mist of cold or chilled water.

In accordance with the present invention, the enclosed treatment space 1 is advantageously operated by a method for permanently monitoring and measuring the atmosphere in each of the chambers 8 and 9, using the sensors 14, 15, and then comparing the data received from the sensors 14, 15 to run a heat-treatment cycle. The data received from the sensors 14, 15 is used to simultaneously and uniformly adjust the output of the heater 10, for heating the heat-transfer fluid, and the output of the regulator 12, for cooling the heat-transfer fluid, if

required. This results in a heat-treatment cycle having temperature step levels and a duration which are preestablished, as a function of the behavior of the load of ligneous material 5 in terms of thermal conductivity and equilibrium between the flow rate and the speed of the heat-transfer fluid between the two chambers 8 and 9. As an alternative, a linear increase in temperature can be achieved.

The sensors 14, 15 are, more particularly, temperature, pressure, humidity and oxygen-analysis sensors arranged in the two chambers 8 and 9. Data from the sensors 14, 15 is used to operate the heater 10 and the blower 11, for continuously circulating the heat-transfer fluid, or to disable the heater 10 and the blower 11 and engage the regulator 12, in particular, when the temperature in the recovery chamber 9 exceeds the temperature in the raised-pressure chamber 8 during temperature increases of the preestablished treatment cycle.

Various pressure and temperature zones are created by the pressure drop resulting from passage of the heat-transfer fluid through the products that are being treated and by the exchange of heat energy between the heat-transfer fluid and the products being treated. This allows for easy and precise control of the operations being implemented, and of the treatment parameters. The levels achieved during a preestablished heat-treatment cycle (which is built into the electronic controls) are determined by equilibrium between the temperatures in the two chambers 8 and 9. This equilibrium is

determined using the formulae:

$$T1 = T2 - \Delta°C,$$ when the temperature is rising, and

$$T2 = T1 + \Delta'°C,$$ when the temperature is falling,

where T1 corresponds to the temperature in the raised-pressure chamber 8, T2 corresponds to the temperature in the recovery chamber 9, and Δ and Δ' correspond to temperature constants illustrated below.

One mode of operation achieved using the method of the present invention, for a ligneous material 5 such as wood with a moisture content of 12 to 14%, will now be illustrated. Levels for executing the illustrated heat-treatment cycle include an increase in temperature, up to 230 degrees Celsius, followed by a controlled drop in temperature which is shown in the following table.

1st level	40°C	Duration: 1 hour after equilibrium	Moisture content 60%
2nd level	60°C	Duration: 2 hours after equilibrium	Moisture content 60%
3rd level	100°C	Duration: 2 hours after equilibrium	Moisture content 40%
4th level	140°C	Duration: 1 hour after equilibrium	O_2<3 and moisture content 20%
5th level	170°C	Equilibrium	
6th level	190°C	Equilibrium	
7th level	210°C	Equilibrium	
8th level	230°C	Equilibrium	

As soon as the oven is brought into operation, the volume of air contained within the enclosed treatment space 1 is caused to circulate, using the blower 11, and the enclosed treatment space is maintained at a pressure above atmospheric pressure. Tappings are made in the chambers 8 and 9 for collecting data relating, in particular, to the flow rate and speed of the heat-transfer fluid inside the enclosed space 1. The volume of air is circulated until the determined flow rate and the determined speed of the air circulating in the two chambers 8 and 9 reach equilibrium, ensuring a uniform transfer of heat to all points of the load of ligneous material 5.

The treatment cycle then begins by operating the heater 10 to heat the heat-transfer fluid. Constant measurement of the oxygen content of the heat-transfer fluid in the raised-pressure chamber 8 and constant measurement of the carbon monoxide (CO) gas content in the upper part of the chambers 8 and 9 allows operation of the heater 10 to be disabled if the oxygen (O) or carbon monoxide (CO) gas concentrations exceed a given level.

If the temperature in the enclosed space 1 reaches 45 degrees Celsius, which corresponds to the threshold for the first temperature level (T1) in the chamber 8, the output of the burners of the heater 10 is reduced. If the temperature continues to rise, the spray boom 12 is operated to sprinkle cold water and then, if necessary, chilled water, into the heat-transfer fluid.

As previously mentioned, the temperature level for the

cycle is reached when the temperature in the raised-pressure chamber 8 is equal to the temperature in the recovery chamber 9 minus a temperature constant Δ, which is preferably equal to 5 degrees Celsius. This temperature level is maintained for the determined duration of the treatment cycle which, in this example, was one hour, during which the temperature is regulated as previously described. As soon as the time duration for the temperature level has elapsed, the electronic controls trigger an increase in temperature to the next level, under the same operating conditions. This continues until the temperature of 230 degrees Celsius is reached.

Advantageously, progression from the level of 100 degrees Celsius is preferably subject to the condition that the volume of the enclosed space 1 contains less than 3% oxygen. Furthermore, the enclosed space 1 of the oven is kept at a pressure of 4 ± 1 mmCE during the treatment cycle. To do this, the enclosed space 1 is provided, in known manner, with a calibrated relief valve to allow any surplus heat-transfer gas generated by the burners of the heater 10 to be discharged.

After the treatment temperature has been reached, the temperature in the enclosed space 1 is lowered, in steps, by spraying cold or chilled water into the heat-transfer fluid using the spray boom 12. These lowered temperature levels are, for example, set at 200, 170, 130, 90 and 50 degrees Celsius. As previously mentioned, progression from one level to the next preferably takes place when the equilibrium of the temperature

(T2) in the recovery chamber 9 is equal to the temperature (T1) in the raised-pressure chamber 8 plus a temperature constant Δ', which is defined, for example, as 20 degrees Celsius.

It will be noted that when the temperature is dropping, the electronic controls record the pressure in the enclosed space 1 and compensate for depression brought about by the reduction in volume of heat-transfer gas by automatically introducing nitrogen to maintain the pressure in the chamber. The electronic controls for the oven are also connected to computerized equipment that allows all of the data from the sensors 14, 15 arranged in the enclosed space 1 to be printed out during a treatment cycle, together with temperature curves, in real time.

To ensure safety within the enclosed space 1, the method of the present invention ensures that if there is an incident involving the heater 10 when the mean temperature of the chambers 8 and 9 is above 120 degrees Celsius, the temperature of the enclosed space 1 is dropped. In particular, the temperature of the enclosed space 1 is dropped until a mean chamber temperature of less than 100 degrees Celsius is reached before any resumption of the treatment cycle is permitted. The temperature of the enclosed space 1 is dropped using the spray boom 12, as previously described.

One of the main advantages of the foregoing method lies in the principle of operation of the oven. To this end, the oven is caused to operate in a natural way, according to the behavior of the products being treated in terms of their thermal

conductivity and their resistance to the release of liquid or degradable substances under the effect of high temperature.

The electronic controls and computerized equipment only serve to monitor the various safety features of the oven, permitting or preventing requested actions and relaying information about operations of the oven. However, to allow such electronic controls and computerized equipment to yield the results expected, the speed at which the heat-transfer fluid is circulated is kept constant in the enclosed treatment space, and through the load of ligneous material, by regulating the flow rate of the heat-transfer fluid.

To obtain good results in terms of the quality and uniformity of the heat treatment being performed, it is preferable not to mix products of different thicknesses or species in the same load. However, the foregoing method advantageously allows the treatment of very different species without having to produce specific programs. The manner in which such an oven operates will automatically adapt to the requirements of the products being treated, although it may be necessary to alter the temperature levels and the durations for which such temperature levels are maintained.

Although the present invention has been described in terms of one particular embodiment, the present invention encompasses all technical equivalents of the means described.